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UNEXPLODED ORDNANCE

A Coordinated Approach to Detection and Clearance Is Needed

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Over the past 2 years, several accounts of the casualties caused by antipersonnel landmines have brought to light the threat such munitions pose years after hostilities cease. The deaths and injuries attributed to these mines each year have been estimated to total about 30,000. Many of the victims are civilians, including children. While the contamination of land caused by landmines and other forms of unexploded ordnance (UXO) may appear to be primarily a Third World issue, closer examination suggests that the problem is shared by developed nations as well.

As you requested, we assessed the extent to which ongoing or foreseeable technology efforts offer solutions to worldwide landmine and other UXO problems. More specifically, we

- reviewed the extent to which the Department of Defense's (DOD) and other agencies' requirements and associated research and development may have application to clearance problems elsewhere in the world,
- assessed the ability of existing or foreseeable technologies to detect and clear landmines and other UXO, and
- identified barriers that could impede the progress or output of such technology.

Background

DOD defines "explosive ordnance" as all munitions, weapon delivery systems, and ordnance items that contain explosives, propellants, nuclear materials, and chemical agents. Included in this definition are bombs, missiles, rockets, artillery rounds, ammunition, mines, and any other similar item that can cause injury to personnel or damage to material. UXO consists of these same items after they (1) are armed or otherwise prepared for action; (2) are launched, placed, fired, or released in a way that they cause hazards; and (3) remain unexploded either through malfunction or design.

Antipersonnel mines pose a particularly difficult clearance problem because they are hard to detect, inexpensive, and prone to proliferation. The Department of State considers landmines to be a distinct class of weapon that is subject to specific doctrinal and international legal controls. Landmines—particularly antipersonnel mines—may pose a greater hazard to innocent civilians than items such as unexploded bombs because they are intended to detonate when a person steps on or near them. Landmines are considered to be a valuable military asset since, by slowing and possibly demoralizing opponents, they multiply the combat impact of defending forces. Their attractiveness to smaller military and paramilitary organizations, such as in the Third World, is further enhanced because mines do not require complex logistics support and are readily available and inexpensive—some can be bought for as little as $3 each.

Over 60 countries, developed and undeveloped, report a need to clear areas from landmine and other UXO contamination. As of December 1994, the Department of State estimated that 80 million to 110 million landmines remain uncleared worldwide, the bulk of which are in undeveloped countries. Most of these countries' economies depend heavily on agriculture and thus are particularly vulnerable because the presence of landmines can deny farmers large sections of land. Within the United States, DOD estimates that over 900 military sites are contaminated with UXO. DOD estimates that it has already cost $10.3 billion through fiscal year 1994 to clean up sites contaminated with hazardous materials, including UXO, and that it will cost an additional $31 billion for future actions. In European countries, millions of bombs, landmines, and other munitions from World Wars I and II still remain uncleared.

Results in Brief

U.S. research and development requirements for UXO detection and clearance technology are broader today than they were during the Cold War years and thus have more in common with the worldwide problem. Traditionally, DOD's technical efforts have supported countermine operations, for which the main priority is rapidly "breaching" or making paths through minefields during combat. "Clearance" differs from breaching because it requires that large areas—such as farmland—be cleared and timeliness is not as critical. With the dissolution of the Soviet Union, U.S. requirements have evolved that have more in common with area clearance than breaching. These other requirements include clearing (1) U.S. military sites of UXO and other hazards and (2) areas and roads needed for conducting operations other than war, such as peacekeeping. Such broader requirements make it likely that research and development

sponsored by DOD will have more direct application to the clearance problems faced by Third World countries. Other agencies, such as the Departments of Energy, Transportation, and Justice also sponsor research and development applicable to the detection and clearance of explosives and other hazards.

U.S. research and development efforts cover a group of technologies that can be categorized as (1) near-term, less advanced technologies that can be put to work immediately and (2) advanced technologies that will take time to develop but could greatly speed up the detection and clearance functions. However, the technologies available today to clear wide areas are inadequate and cannot keep pace with the number of landmines being emplaced annually. For example, the United Nations estimated that in 1993, 2.5 million mines were emplaced, while only 80,000 were removed. The most effective techniques, such as hand-held probes and metal detectors, are time-consuming, expensive, and labor-intensive. While heavy mine clearing equipment, such as plows, is suited to breaching paths, it is not practical for clearing large areas. Also, current technologies do not perform well against newer, more advanced munitions. For example, metal detectors are ineffective against newer antipersonnel mines that contain little or no metal. Moreover, recent technology demonstrations showed the more advanced methods to be much less reliable than traditional methods.

Several factors limit the potential output from the U.S. investment in technologies related to the detection and clearance of landmines and other forms of UXO. Although numerous U.S. organizations within and outside DOD are sponsoring technologies that could have application to the problem, no overarching, governmentwide strategy or organization exists to ensure that the most is gained from these various efforts. Moreover, it is difficult to develop an accurate estimate of how much funding these organizations are collectively providing for applicable technologies or whether that level of investment is sufficient. The House Committee on National Security recently took a step to address this problem by directing the Secretary of Defense to develop a plan to improve the management and cooperation of technology efforts directed at landmine and other UXO clearance.[1] Other barriers to technical solutions include the relative ease with which inexpensive improvements in mine designs have outstripped detection and clearance methods, the unique area clearance challenges Third World countries pose, and the difficulty of controlling the proliferation of antipersonnel landmines.

[1]National Defense Authorization Act for Fiscal Year 1996, H.R. Rep. 104-131, p. 95.

Emerging U.S. Requirements May Spawn Technology That Is More Applicable to Worldwide Problems

Comparison of Combat and Noncombat Clearance Requirements

A primary focus of DOD's research and development activities in detection and clearance has been on the countermine mission in support of combat operations. In combat, mines are seen as an obstacle in the way of an attack or a maneuver; overcoming these obstacles involves rapidly detecting, breaching, and marking paths while under assumed enemy fire. Some casualties are expected and accepted. Most of these countermine operations are destructive because heavy or destructive equipment such as plows, rollers, flails,[2] and explosives—are used to breach enemy minefields. Once breached, the cleared paths are marked so that following forces can traverse the minefield safely. These operations do not require the identification of the exact locations of the mines. Also, the operations do not require that an entire area be cleared unless the area is to be occupied for future operations.

Detecting and clearing landmines and other UXO in noncombat situations in some ways is less demanding and in other ways more demanding than countermine operations. In noncombat situations, neither time nor enemy fire is a constraining factor, so detection and clearance operations take place under much less hostile circumstances. On the other hand, because the noncombat objective is to render an area safe and worthwhile to repopulate, the corresponding objective is to detect and clear all landmines and other UXO. Thus, not only must contaminated areas be positively identified to very high standards of reliability, but efforts must be made to find all munitions and other hazards. Once found, the explosives must be removed or neutralized in an environmentally sound way. In the process, care must be taken not to destroy the land or infrastructure.

These differing demands produce corresponding differences in research and development priorities. For example, money spent to develop an

[2]Flails generally consist of hardened cylinders with heavy chains that pummel the ground by spinning. They are mounted on heavy vehicles.

improved plow for an M-1 tank may be a good investment for the countermine mission, but it is not necessarily practical for noncombat operations. Similarly, a detection technology that takes a lot of time may work well in a noncombat situation, but be too slow for countermine operations. On the other hand, countermine and noncombat missions do share some requirements and benefit from the attendant technologies. If a military force plans to occupy a mined area, it must use detection and clearance technologies and methods aimed at achieving as near as possible a 100-percent clearance.[3] Also, it is beneficial to combat forces to detect the presence of minefields so that they can be avoided, if possible. Such a detection capability would also benefit noncombat clearance operations, even if the exact locations of individual munitions could not be pinpointed, because unsafe areas could be posted or cordoned off and avoided by civilians.

Broader U.S. Area Clearance Requirements Have Emerged

Several factors have converged into a set of emerging U.S. requirements that go beyond the countermine mission and address the need for detecting and clearing all hazards, including landmines and other UXO. Following the dissolution of the Soviet Union, the United States has become more involved with operations other than war, including special operations, low-intensity conflicts, and peacekeeping. These operations require U.S. and other forces to routinely clear operational areas and infrastructure—such as roads and buildings—of mines and other explosives. In addition to open area clearance, DOD has developed urban warfare requirements that include the detection and clearance of mines and booby traps. It should be noted that while U.S. military personnel will perform such operations when U.S. interests are at stake, it is against U.S. policy for them to physically remove landmines from other countries for humanitarian purposes.

In addition, the closing of numerous bases per the recommendations of the base realignment and closure process and the environmental cleanup of other defense sites have generated a sizeable clearance requirement. Many of these sites, such as test ranges, impact ranges, and training sites, contain large areas of UXO contamination. Clearing these areas—even partially—so that they can be used for other purposes requires detection and clearance methods to meet a 100-percent clearance objective. The research and development efforts sponsored by DOD to support operations such as peacekeeping and base cleanup are likely to have more direct

[3]DOD's specific requirement is 99.9-percent clearance at a depth of 18 inches.

application to the clearance problems faced by Third World countries than those efforts supporting countermine operations.

Other U.S. agencies besides DOD are responsible for detecting and clearing explosives and other hazards. For example, the Departments of Treasury, Justice, and Transportation conduct or sponsor research and development of technologies to help curb terrorism, such as detecting explosives and weapons in airports, aircraft, and public buildings. The Department of Transportation is also responsible for detecting subsurface flaws in roads and bridges. The Department of Energy and the Environmental Protection Agency are responsible for detecting hazardous materials, such as buried radioactive and chemical waste. These research and development efforts have some commonality with those needed to detect and clear landmines and other UXO. Specifically, they involve (1) detecting the presence and exact location of explosive and hazardous materials in the open, underground, or hidden in a building or vehicle; (2) removing or neutralizing the materials; and (3) using methods that allow maximum standoff distances.

European countries have had broad clearance requirements for a long time as they are still clearing areas from World Wars I and II. For example, in Verdun, France, millions of UXO items from World War I still have not been found or cleared. Germany has been clearing UXO from Berlin since World War II ended. The United Kingdom has clearance requirements both at home following World War II bombardments and abroad. For example, after the Falkland Islands war, the United Kingdom sponsored efforts to detect and clear remaining mines there.

An Ideal Solution Is Not Foreseeable Based on Known Technologies

Current Technology

Currently, hand-held probes, metal detectors, trained dogs, and mechanical breaching equipment are considered the most effective tools to detect and/or clear landmines and other UXO. These methods are slow, costly, and labor-intensive. They mainly find landmines at or near the surface, although some metal detectors can find larger, more deeply

buried UXO items because of their greater metal content. Although current methods offer the greatest assurance that an area is safe to use, they are also quite dangerous because they put the operator in close proximity to the explosive. For example, in the post-Gulf War cleanup of Kuwait, 84 operators, including at least 2 private U.S. contractors, were killed using these methods. This number of fatalities is more significant when one considers that the mines in Kuwait were easier to find than in some Third World countries because they were in sand and had been placed in patterns according to known military doctrine.

Metal detectors have been in use since World War II and are still the most effective sensors for use against landmines and other UXO. There are two types of metal detectors. One detects anomalies in the earth's magnetic field caused by ferrous (iron-based) materials. The other creates an electromagnetic field that can detect both ferrous and non-ferrous metals. Improvements made to metal detectors have reportedly been in processing sensor information, weight reduction, and improved sensitivity to disturbances in the magnetic field caused by metallic objects. Detection of trace metal elements and debris—found in most soils—still leads to a high level of false alarms since operators are often unable to discriminate between a metal fragment and a mine. False alarms translate into increased workload because each detection must be treated as if it were an explosive. Efforts to duplicate the knowledge, skills, and abilities of a proficient operator through computers and artificial intelligence have not yet proven successful.

Trained dogs have proven effective at detecting hidden explosives. South Africa has developed a system that uses blast-hardened vehicles to collect air samples from geographical sectors in filter canisters. The dogs can then detect which canister—and thus which sector—contains any evidence of explosives. These sectors can then be cleared using traditional methods. Since dogs have been extremely efficient in pinpointing the location of landmines, research and development efforts have been underway to duplicate the dogs' abilities through development of artificial biosensors, spectrum analysis, and computer intelligence. However, no sensor technology has been developed that can replicate the dogs' ability to sense explosives.

Mechanical equipment used in combat operations to clear mines includes armored vehicles equipped with devices such as plows, flails, and rollers. This equipment clears a path by pushing mines aside or detonating them. It is not effective in rough or rocky terrain and against more advanced,

off-route or wide-area mines. However, these advanced mines do not yet make up a large portion of the landmines already emplaced in Third World countries. For these reasons, and because of the potential environmental impact, such as pollution and soil erosion, heavy mechanical equipment is of limited use for wide-area clearance. Another technique used in combat is the explosive line charge. The line charge is a cord or rope of explosives that is fired across a suspected minefield. The explosives are set off to detonate or disable nearby mines and thus clear a path. Line charges have been used since World War II and are still being improved today.

All of these methods are slow and costly. For example, the Navy estimates that it would take $2 billion and 20 years to clear the 28,800-acre Hawaiian island of Kaho'olawe to achieve a 4-foot depth needed for farming. The services have used the island as a bombing range since 1941. Similarly, we have previously reported that a study of the Jefferson Proving Ground found that current cleanup technologies were not practical for removing the UXO from the installation's 51,000 heavily forested acres.[4] Army officials estimated that cleanup estimates for the installation could range from $5 billion to $8 billion. These estimates underscore the current challenge the United States faces in cleaning up millions of acres of its defense sites. The worldwide challenge is even more daunting.

Advanced Technology

Generally, more advanced technologies being pursued aim to make the detection of landmines and other UXO quicker, safer, and more cost-effective. They employ sensors that can be operated from remote distances, such as from manned or unmanned ground and air vehicles. However, no revolutionary area clearance technology with acceptable reliability has been forthcoming. Most of the advanced technologies have drawbacks such as weaknesses under certain environmental conditions or impractical power requirements. At this point, the more promising efforts involve using a combination of technologies either concurrently or sequentially. While standoff sensors do not perform as well as current hand-held methods, they can perform initial searches for landmines and other UXO to help identify contaminated areas that are ultimately cleared using traditional methods.

Advanced sensor technologies with application to detection and clearance can be grouped as follows: infrared sensors, ground-penetrating radars, microwave, photon backscatter, nuclear or thermal neutron analysis, and lasers. Their characteristics are summarized in table 1.

[4]Military Bases: Environmental Impact at Closing Installations (GAO/NSIAD-95-70, Feb. 23, 1995).

Table 1: Advanced Detection and Clearance Technologies

Technology	Characteristics	Comments
Infrared sensor	Looks for differences in surface radiation caused by objects or disturbances in the soil. Affected by ambient temperatures, high levels of soil moisture, and vegetation density.	Only effective against UXO at or near the surface and against UXO that has not been in the ground too long.
Ground-penetrating radar	Emits short pulses of electromagnetic energy of various wave lengths (including microwave) into the ground. Returning signals are collected by arrays of detectors.	Effectiveness varies with changes in atmospheric conditions. Ineffective in moist soils without a high-power system; cost-effective means of meeting these power requirements in the field is lacking. Trade-offs exist between radar wave length, depth of ground penetration, and resolution.
Microwave	In addition to its application to ground-penetrating radar, a high-powered microwave system could be used to neutralize UXO in situ.	Large power needs. Can affect soil characteristics and harm life forms and equipment.
Photon backscatter	Scans the ground with a pencil-thin beam of X-rays. X-rays produce scattered returns from objects that are collected by detectors on either side of the vehicle and processed.	Early in development. Has large power needs, slow speed, and a small footprint. Can change soil characteristics and harm life forms and equipment. Has a high data processing requirement.
Nuclear or thermal neutron analysis	One application uses californium (a radioactive element) to excite explosive material to release gamma rays that can be detected. Another application excites hydrogen in an explosive that releases neutrons that can be detected.	Early in development. Has a small footprint. Hydrogen sensors are not effective in moist soil.
Laser	Irradiates small areas of ground so mines and other UXO at or near the surface may react to this type of laser energy by emitting heat and light, unlike the surrounding soil. Other sensors, such as infrared and hyperspectral, may be used to detect the reactions and pinpoint the UXO. Also being developed to neutralize and to help map locations.	Neutralization and irradiation types have high power requirements. Can affect soil characteristics and harm life forms and equipment. Hyperspectral sensor's large data processing requirements tax the capacity of airborne platforms.

Some promising recent research and development efforts involve coupling sensor technologies. For example, the Army has the Airborne Standoff Minefield Detection System under development that combines infrared and laser sensors. The Marine Corps has a project underway that couples ground-penetrating radar and infrared sensors. The Department of Energy has initiated a subsurface imaging program utilizing ground-penetrating radar and seismic measurements. Several projects are also underway that link sensors with the satellite-based Differential Global Positioning System. Linkage to this system can help map geographical locations of landmines and other UXO.

Advances in mine technologies have been made that can reduce the amount of contamination posed by landmines and other UXO in the future. Specifically, DOD has developed self-destruct mechanisms that detonate

munitions a specified time after they have been deployed. According to DOD officials, such mechanisms have been incorporated into U.S. landmines since 1979. While not foolproof—self-destruct mechanisms have demonstrated 90 percent reliability in testing—they do reduce the risk of injury to innocent civilians. DOD officials noted that not all U.S. landmines contain self-destruct mechanisms because some minefields are intended to stay active indefinitely. Self-destruct mechanisms are currently being developed for submunitions, but are not yet fielded. DOD is also developing mechanisms that can detonate munitions on demand from remote locations.

Technology Demonstrations Have Not Identified an Ideal Solution

Although numerous efforts to advance technology have been made, demonstrations have not produced an ideal solution. The Army Environmental Center, in cooperation with Naval Explosive Ordnance Disposal Technology Division,[5] has been conducting an Advanced Technology Demonstration for the detection, identification, and clearance of UXO, including landmines. The demonstration was mandated by the Congress in fiscal years 1993 and 1994. The purpose of this effort was to demonstrate the best available off-the-shelf detection and clearance technologies. Thirty-three projects were demonstrated, with most coming from private industry and a few from government laboratories. The demonstration projects represented airborne, ground vehicle, and man-portable platforms with metal detectors, ground-penetrating radar, and infrared sensors. The test areas included a variety of ordnance buried at realistic depths; however, the terrain was relatively benign—open, clear, and level. Target processing software and clearance technologies were also demonstrated. Some used multiple sensors, such as ground-penetrating radar with infrared or metal detectors.

The goals of the demonstrations were to (1) survey large areas; (2) determine density of UXO, as well as type, depth, and exact location; (3) discriminate between UXO and other objects; and (4) demonstrate UXO detection, identification, and clearance systems as integrated technology. UXO, scrap metal, and other objects were planted in two courses—one for ground systems and one for airborne systems.

Demonstration results showed that none of the technologies, either individually or coupled, came close to approaching 100-percent clearance. UXO detection ranged from 0 to 59 percent, with the ground-based systems

[5]Although this organization originated under the Navy, it is jointly staffed and funded to conduct UXO research, development, and operations for all three services.

performing the best, especially when vehicle-mounted and man-portable systems were used together. However, the ability to separate UXO from false alarms was dismal for all technologies demonstrated. Again, the ground-based systems were the most reliable, but the system with the highest detection rates did not finish the course in the required time. All but one airborne system completed the course in the required time, but the airborne systems were the least effective of all systems. The clearance systems in the demonstration, which relied on robotics excavations, were considered effective but time-consuming.

Several Factors Could Impede the Progress of Future Efforts

Many Organizations Are Involved With Detection and Clearance Technologies, Operations, and Policies

We identified over 20 U.S. organizations that directly or indirectly conduct or sponsor research and development with application to detection and clearance, review related programs and policies, conduct detection and clearance operations, or provide funds or related training. Some of these organizations are shown in table 2.

Table 2: U.S. Organizations Involved in Detection and Clearance Technologies

Organizations	Conducts or sponsors research and development	Reviews research and development policies or programs	Conducts or sponsors detection and clearance operations and/or training
Office of the Secretary of Defense, Defense Acquisition and Technology	X	X	X
Office of the Joint Chiefs of Staff	X	X	
Office of the Secretary of Defense, Special Operations and Low-Intensity Conflict	X	X	X
Advanced Research Projects Agency	X	X	
Army Environmental Center	X	X	X
Program Executive Officer for Armored Systems Modernization, U.S. Army	X	X	X
Army Communications Electronics Command, Mine, Countermine, and Demolitions	X	X	X
Army National Ground Intelligence Center		X	
Air Force Materiel Command	X	X	X
Naval Explosive Ordnance Disposal Technology Division	X	X	X
Office of Naval Research	X	X	
Marine Corps Amphibious Warfare Technology	X	X	X
Marine Corps Intelligence Activity		X	
Department of Energy, Environmental Restoration and Waste Management, Technology Development	X	X	X
Environmental Protection Agency	X	X	X
Department of Justice, Federal Bureau of Investigation	X	X	X
Department of Transportation, Federal Aviation Administration	X	X	X
Department of State, Bureau of Political-Military Affairs		X	X
U.S. Agency for International Development			X
Interagency Working Group on Demining and Landmine Control		X	X
Department of Treasury, Bureau of Alcohol, Tobacco, and Firearms	X	X	X

The number of U.S. organizations involved is greater than indicated in the table because the different offices in the service commands are involved with one or more forms of UXO, national laboratories conduct research and development for DOD, and individual contractors work for different agencies or on commercial applications. Organizations outside the United States are also involved with detection and clearance technologies. For

example, the United Nations is actively involved with clearing landmines from Third World countries and promoting policies to counter proliferation. Many individual countries have been working on countermine operations and UXO clearance and are developing clearance technologies and methods. These countries include the United Kingdom, France, Sweden, Germany, Russia, and South Africa.

Research and Development Efforts Are Not Well-Coordinated

No formal mechanism or strategic plan exists to ensure that a fully coordinated U.S. research and development effort is leveraged at the problem. This situation exists because the organizations involved with technologies related to detection and clearance are seeking solutions to more narrowly defined problems that fall under their purview. For example, the combat branches of the military services have traditionally pursued solutions to the countermine problem. The Department of Energy and the Environmental Protection Agency sponsor research and development to detect and clear hazards such as subsurface radioactive, chemical, and other waste. The Federal Aviation Administration and the Federal Bureau of Investigation sponsor research and development to see through concealments to detect explosives, firearms, and contraband. More recently, DOD has sponsored technology efforts to facilitate cleanup of defense sites.

Nonetheless, when requirements are more broadly defined as the detection and clearance of harmful, hidden objects or voids (such as concrete flaws and underground facilities), the technologies that various agencies employ or are developing for their own missions can be related. For example, the Army, the Navy, and the Department of Energy are either sponsoring research and development in or have experimented with ground-penetrating radars. This does not necessarily mean that unwanted duplication is occurring, but it does illustrate the potential for one agency to be aware of and possibly take advantage of relevant technologies other agencies are working on.

Some interagency coordination occurs on an ad hoc or narrow basis, such as through symposia, technology demonstrations, and joint programs, but this does not necessarily provide a firm basis for technology exchange. Most of the participants at an interagency UXO forum that we sponsored in May 1995 cited the lack of a coordination mechanism as a barrier to making progress in technologies applicable to the detection and clearance of landmines and other UXO. They also pointed out the need for an overarching research and development plan for these technologies and for

an entity to be charged with overseeing and coordinating the relevant technology efforts.

Even within DOD, full coordination between agencies working on detection and clearance technologies is not occurring. In particular, agencies that are responsible for cleaning up military sites and those responsible for countermine missions are not always working together, even though they share interests in many of the same technologies. Currently, two demonstrations of detection technologies for use against landmines and other forms of UXO are underway. One is being conducted by the Army Communications Electronics Command, which sponsors countermine research and development, and the other is being jointly conducted by the Army Environmental Center and the Naval Explosive Ordnance Disposal Technology Division. Neither organization has participated in the other's demonstration. Perhaps illustrative of the need for broader coordination is the fact that several similar demonstrations have been conducted in the past 5 years by the Department of Energy, the Army, and the Marine Corps.

Several cooperative efforts have been undertaken by U.S. organizations. In September 1993, the National Security Council established what became known as the Interagency Working Group on Demining and Landmine Control. The group plans, funds, and organizes operations to remove landmines from Third World countries. It also established a research and development subgroup to promote improvements in area clearance technologies. The group includes representatives from the Departments of Defense and State, the U.S. Agency for International Development, and the Central Intelligence Agency. However, not all U.S. organizations involved in technology applicable to the detection and clearance of landmines and other UXO are represented.

Within DOD, several organizations have begun to develop mechanisms for coordinating, planning, and budgeting countermine research and development activities. While these efforts may improve coordination, they involve agencies within the countermine community. The Navy and the Marine Corps have recently initiated efforts to formally recognize clearance technology as beneficial to their individual missions. The Marine Corps and the Navy have established a Mine Warfare Program Executive Office and a Shallow Water Mine Countermine Steering Committee. The Army and the Marine Corps have established a joint demonstration effort that is directed toward identifying advanced concepts for a potentially integrated countermine capability. The Mine Countermeasures Subpanel

under the Joint Directors of Laboratories, established within the last 2 years, is a multiservice mechanism that involves all of the services.

The number of different U.S. organizations supporting relevant research and development also makes it difficult to gauge the level of funding the United States is devoting to technologies that can detect UXO and other hazardous materials. For example, based on fiscal year 1996 budget estimates, the Departments of Defense, Energy, and Transportation could invest somewhere between $75 million and $150 million in research and development efforts that may have some application to the detection and clearance of landmines and other UXO. However, it is unclear how much of that amount is directly related to detection and clearance technologies that have application to noncombat situations. Accordingly, it is difficult to determine whether the United States is getting the most from its level of investment in these technologies or whether the current level matches known national requirements.

Other Impediments to Seeking Technical Solutions

Even if the maximum output could be gained from the various organizations sponsoring research and development, several other factors could blunt the effect of technology gains. One factor is mine technology's ability to stay ahead of detection and clearance technologies. For example, some new mines are made of plastic, composite, and ceramic components, and have little or no metallic content. Thus, the effectiveness of the metal detector, which is one of the most widely used detection technologies, is limited against such mines. Some mines are designed to prevent premature detonation, such as when they are blasted with explosives or dropped. For example, some have air bladders that react to blast or overpressure and inflate to disarm and, then, rearm to await their intended targets. In addition, scatterable mines have been developed that can be deployed by air, increasing the number of these mines that can be rapidly deployed exponentially. Despite these advances, service officials note that even the traditional research and development efforts devoted to the countermine mission have historically been accorded relatively low funding priority.

The characteristics of the country to be cleared can also affect the applicability of a given technology. For example, detection and clearance equipment to be used by Third World countries must be inexpensive to buy and maintain as well as easy to understand and use. From a cost and logistics support perspective, a sophisticated military technology may not be practical in such circumstances. Landmine and other UXO detection and clearance equipment must be effective given the geographical and terrain

characteristics at hand. For example, soil with traces of metal elements can confuse metal detectors, and rocky soil impairs hand-held probes. High levels of moisture in soil can affect the performance of detection technologies. Mountainous or forested terrain makes technologies that depend on large or heavy vehicles impractical.

Finally, despite the efforts of the United Nations, the landmine problem continues to worsen. Each year, many more mines are emplaced than can be removed. For example, the United Nations estimated that in 1993, 2.5 million mines were emplaced, while only 80,000 were removed. The primary mechanism for controlling the use of landmines is contained in Protocol II of the 1980 Convention on Conventional Weapons. The protocol was designed to reduce the harm to innocent civilians. It limits the use of landmines and booby traps to military objectives, prohibits their use against civilian populations, requires that parties to a conflict try to ensure that the location of minefields is recorded, and requires that scatterable mines contain self-destruct mechanisms or have their location recorded.

The protocol has been largely ineffective for several reasons. First, it covers only international conflicts, while most landmine-related injuries have resulted from civil or internal conflicts. Second, it does not regulate the production, stockpiling, transfer, or export of landmines. Third, it contains no provision for monitoring compliance, conducting enforcement, or penalizing violators.

The Congress and the Executive Branch Have Taken Actions to Help Resolve the Landmine Problem

The executive branch and the Congress have taken several actions over the past 3 years to curb the proliferation of landmines and improve research and technology directed at detecting and clearing landmines and other UXO. In October 1992, the United States adopted a unilateral export moratorium on antipersonnel landmines, which has been extended until 1996. According to DOD, the United States was the first country to take such a step, which has led other countries to follow suit. In his address to the U. N. General Assembly in 1994, the President called for the eventual elimination of antipersonnel landmines and for the international control of production, export, and stockpiling as the first step toward elimination. On March 24, 1995, the Senate gave its advice and consent and the President ratified the 1980 Convention on Conventional Weapons as well as Protocol II. In addition, the United States was an active participant in the July 1995 International Meeting on Mine Clearance in Geneva, Switzerland.

Beginning on September 25, 1995, 48 nations will convene as full parties to reopen the Convention on Conventional Weapons and conduct a conference to review the Convention, including Protocol II on landmine use. Other signatories and observers are also expected to participate in the conference, which will consider several proposals to strengthen Protocol II. The executive branch strongly supports strengthening the Convention by (1) extending its scope to include internal conflicts, (2) limiting the use of non-self-destructing antipersonnel landmines to marked and monitored areas, (3) making the party that placed the mines responsible for clearing them, (4) banning nondetectable mines, and (5) creating a system to verify the restrictions on mine usage.

In the conference report accompanying the National Defense Authorization Act for Fiscal Year 1994, the Congress directed DOD to undertake a large-scale detection and clearance technology demonstration. Although this demonstration did not produce breakthrough solutions, it did establish a baseline for assessing the state of the art in UXO detection technologies. In the conference report accompanying the National Defense Authorization Act for Fiscal Year 1995, the Congress directed the Army to develop technologies for mine detection and neutralization for use in humanitarian mine removal operations and operations other than war. Such technologies were to be capable of being shared in an international environment. In its report on the fiscal year 1996 DOD authorization bill, the House Committee on National Security cited the need for a central authority to plan, oversee, and coordinate the research, development, and acquisition of the technology applicable to area ordnance clearance. It directed the Secretary of Defense to submit a plan that defines research and development priorities, program management, and cooperative activity with international programs.

Recommendations

The numerous research and development efforts funded by the United States and by other countries could be more productive if they were linked by a common purpose—the detection and clearance of landmines and other UXO. Such a common purpose should complement—not supplant—individual missions, such as countermine, cleanup of hazardous waste, cleanup of bases, and humanitarian demining, by serving as a vehicle for sharing technical progress and avoiding duplication.

Accordingly, we recommend that the Secretary of Defense include in the research and development plan called for by the House Committee on

National Security, a proposal on how a multiagency clearinghouse function could be performed to

- maintain visibility over all federally funded research and development projects with application to detection and clearance of landmines, other UXO, and other hazards;
- develop an overarching strategy that encompasses both near-term and long-term priorities for detection and clearance technologies; and
- serve as an active link to relevant international and private research and development efforts.

Such a proposal should be based on consultation with the Secretary of State, the Secretary of Energy, and the heads of other federal agencies that sponsor research and development that may have application to detection and clearance of landmines, other UXO, and other hazards.

We further recommend that the Secretary of Defense designate an executive agent to serve as a clearinghouse for research and development efforts within DOD that may have application to detection and clearance of landmines, other UXO, and other hazards. The role of such an agent would be to gain visibility over and to leverage these efforts against the broader problems of detection and clearance rather than to champion an individual mission.

Agency Comments

Both DOD and the Department of State concurred with our recommendations. In its comments (see app. I), DOD stated that it could prepare a proposal detailing the functions of a multiagency clearinghouse and that statutory language could facilitate implementation of the proposal by specifically identifying the roles and responsibilities of the participating agencies. DOD also said that it would identify an executive agent to serve as a clearinghouse within DOD as part of the February 1996 plan required by the House National Security Committee.

The Department of State commented that it endorsed the need for more coordinated research and for the identification of a lead institution in U.S. government research and development (see app. II).

Both agencies provided specific technical clarifications that we incorporated in the report, as appropriate.

Scope and Methodology

We reviewed pertinent reports, documents, and legislation relevant to detection and clearance technologies. We also interviewed officials from the Office of the Secretary of Defense; the military services' program offices, laboratories, and intelligence agencies; the Departments of Energy and State; the Army Environmental Center and the Naval Explosive Ordnance Disposal Technology Division; the Advanced Research Projects Agency; the United Nations; and the National Academy of Science. We also attended related conferences and symposia and spoke with industrial and technical representatives from other countries, such as England, South Africa, Austria, Germany, and Sweden.

In May 1995, we hosted a forum to discuss landmine and other UXO problems, technologies, and solutions. Participants included representatives from the Office of the Secretary of Defense, the military services, the Departments of State and Energy, the Advanced Research Projects Agency, the United Nations, and CMS, Inc., a firm that conducted mine clearance operations in Kuwait. The key questions that the forum attempted to address were (1) whether a legitimate UXO requirement—different from the countermine requirement—exists that warrants the pursuit of technological solutions; (2) whether the research and development efforts currently planned or underway constitute a sound approach toward such a solution; (3) what factors (technical, managerial, or otherwise), if any, impede the advancement of detection and clearance technology for landmines and other UXO; (4) what change in approach to technology development (technical, managerial, or otherwise), if any, should be made in the near term and long term; and (5) who or what organizations should take the lead in instituting change and ensuring that the efforts in developing landmine and UXO detection and clearance technology are well orchestrated.

We conducted our review from September 1994 to July 1995 in accordance with generally accepted government auditing standards.

We are sending copies of this report to other interested congressional committees; the Secretaries of Defense, Energy, and State; the Secretaries of the military services; and the Secretary General of the United Nations. We will also make copies available to others upon request.

Please contact me at (202) 512-5140 if you or your staff have any questions concerning this report. Major contributors to this report were Sharon Cekala, Paul Francis, MaeWanda Michael-Jackson, and James Dowd.

Mark E. Gebicke, Director
Military Operations and
Capabilities Issues

Comments From the Department of Defense

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000

ACQUISITION AND TECHNOLOGY

August 29, 1995

Mr. Mark E. Gebicke
Director, Military Operations and Capabilities Issues
National Security and International Affairs Division
U.S. General Accounting Office
Washington,D.C. 20548

Dear Mr. Gebicke:

This is tne Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "UNEXPLODED ORDNANCE: Detection and Clearance Capabilities Can Benefit From a Coordinated Approach," dated July 31, 1995 (GAO Code 703066/OSD Case 9988). The DoD generally concurs with the draft report.

On the whole, the GAO's review and subsequent publication of their findings and recommendations will afford the DoD an excellent opportunity to refocus the fragmented efforts that relate to the detection and neutralization of unexploded ordnance. Clearly, the problem is of enormous magnitude and the DoD needs to apply its limited resources in the most cost-effective manner. While the two recommendations are logical derivatives of the study, implementation will be a significant challenge, particularly from the perspective of integrating non-DoD programs into a cohesive strategy. Since technology and materiel acquisition are the centerpieces of your review, the DoD will most likely charter an existing acquisition organization with the responsibility of serving as the clearinghouse.

See comment 1.

There are two major concerns which we encourage you to address in the final report. First, a long-term solution that was not discussed in the report is the ongoing efforts to incorporate self-destruct mechanisms in the DoD's high density munitions which would limit further proliferation of unexploded ordnance on the battlefield. Second, there is a misleading reference to U.S. forces conducting humanitarian demining operations. Such is not the case; U.S. forces train the host nation personnel to perform the demining operation. The host nation personnel are then responsible for conducting the demining operation.

See comment 2.

The Department's detailed response to the recommendations is enclosed. Additional specific technical comments which should be included to improve the overall quality of the draft report were provided separately. The Department appreciates the opportunity to review the draft report.

George R. Schneiter
Director
Strategic & Tactical Systems

Attach
A/S

**GAO DRAFT REPORT - DATED JULY 31, 1995
(GAO CODE 703066) OSD CASE 9988**

"UNEXPLODED ORDNANCE: DETECTION AND CLEARANCE CAPABILITIES CAN BENEFIT FROM A COORDINATED APPROACH"

**DEPARTMENT OF DEFENSE COMMENTS
ON THE GAO RECOMMENDATIONS**

*****

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense include in the research and development plan called for by the House Committee on National Security a proposal on how a multi-agency clearinghouse function could be performed to

-- maintain visibility over all Federally funded research and development projects with application to detection and remediation;

-- develop an overarching strategy that encompasses both near-term and long-term priorities for detection and clearance technologies; and

-- serve as an active link to relevant international and private research and development efforts.

The GAO noted that such a proposal should be based on consultation with the Secretary of State, the Secretary of Energy, and the heads of other Federal agencies that sponsor research and development that may have application to detection and remediation of landmines, other unexploded ordnance (UXO), and other hazards. (p. 25/GAO Draft Report)

Now on pp. 17-18.

DoD RESPONSE: Concur. The DoD can prepare a proposal to accomplish the aforementioned objectives. Implementation of the proposal can be facilitated by statutory language which specifically identifies the roles and responsibilities of the various participating Federal agencies. A proposal will be included in the plan required by the House National Security Committee and will be submitted by February 15, 1996.

Now on p. 18.

RECOMMENDATION 2: The GAO recommended that the Secretary of Defense designate an executive agent to serve as a clearinghouse for research and development efforts within the DoD that may have application to detection and remediation of landmines, other UXO, and other hazards. The GAO explained that the role of such an agent would be to gain visibility over and to leverage these efforts against the broader problems of detection and remediation, rather than to champion an individual mission. (p. 25/GAO Draft Report)

DoD RESPONSE: Concur. The DoD's identification of an executive agent to serve as the clearinghouse will be provided in the plan required by the House National Security Committee language.

The following are GAO's comments on the Department of Defense's (DOD) letter dated August 29, 1995.

GAO Comments

1. A discussion of self-destruct mechanisms has been added to the report.

2. Language has been added to the report to recognize the fact that U.S. forces do not conduct humanitarian demining missions.

Comments From the Department of State

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

United States Department of State

Chief Financial Officer

Washington, D.C. 20520–7427

AUG 17 1995

Dear Mr. Hinton;

We appreciate the opportunity to provide Department of State comments on your draft report, "UNEXPLODED ORDINANCE: Detection and Clearance Capabilities Can Benefit From a Coordinated Approach," GAO Job Code 703066.

If you have any questions concerning this response, please call Colonel Robert F. Carty, PM/ISP, at (202) 647-0622.

Sincerely,

Richard L. Greene

Enclosures:
As Stated.

cc: GAO - Mr. Francis
State/PM/ISP - Colonel Carty

Mr. Henry L. Hinton, Jr,
Assistant Comptroller General,
National Security and International Affairs,
U.S. General Accounting Office.

SUBJECT: GAO Draft Report: "UNEXPLODED ORDNANCE: Detection and Clearance Capabilities Can Benefit From a Coordinated Approach," GAO Job Code 703066

GENERAL COMMENTS:

-- We endorse the report's recommendation for more coordinated research and for the identification of a lead institution in USG research and development as well as coordination with the private sector and other research organizations.

See comment 1.

-- The report should address the future funding of research and development efforts. It implies that more funds should be appropriated in FY96 and beyond; however, such a recommendation should be made explicit.

See comment 2.

-- The Administration has adopted the use of "landmine" as one word which may not be found in most dictionaries, but is common in military terminology.

See comment 3.

-- Despite our earlier comments, there remains a serious problem with the report blurring the distinction between landmines and unexploded ordnance. Although the difference may seem trivial in this context, maintaining a distinction is extremely important in other areas of USG policy-making.

See comment 4.

-- It may be useful to provide a summary of current USG mine clearance programs underway to better understand the intended context for new technologies.

See comment 5.

-- USAID is not mentioned in the report as a player even though it is represented on the IWG and plays an active role in two of the IWG subgroups. USAID's interest in and funding of demining activities has been to support (1) landmine clearance, training, and mine awareness in relatively stable countries (such as Afghanistan, Cambodia, and Mozambique) where the presence of landmines inhibit or have a direct negative impact on achieving sustainable development objectives such as increasing agricultural production or improving the flow of goods and services, and (2) the clearance of landmines essential to the provision of emergency/disaster assistance and the return of refugees, etc. In a related activity, USAID monies support the War Victim's Fund for protheses and other types of rehabilitation assistance which benefits UXO and landmine victims.

The following are GAO's comments on the Department of State's letter dated August 17, 1995.

GAO Comments

1.We have not concluded that more research and development funds should be appropriated in the future. As noted in the report, because of the number of organizations involved and the various projects underway, it is difficult to estimate the current level of U.S. investment in technologies related to detection and clearance of landmines and other UXO. We believe that once a multiagency clearinghouse function and an executive agent for DOD are established, the data can be assembled to establish the current U.S. level of investment and determine whether that level is appropriate. Such analysis, along with an updated assessment of the landmine and other UXO problem, should be the basis for determining the level of future funding.

2. Change adopted.

3.We have modified our wording throughout the report in reference to landmines and other UXO. We have explicitly recognized the distinction the Department of State makes for the purposes of policymaking. However, we note that (1) landmines are included in the DOD definition of UXO and (2) for the thrust of this report—research and development to advance technology—it is important to stress the similarities between the problems posed by landmines and by other UXO rather than the distinctions.

4.A summary of all U.S. mine clearance programs currently underway was beyond the scope of our work. DOD may be able to provide a reasonable summary at this time, but a better summary would likely be possible following the establishment of the multiagency clearinghouse function.

5.The U.S. Agency for International Development is included in the report as a member of the Interagency Working Group on Demining and Landmine Control. We have also added the agency to our list of U.S. organizations contained in table 2.

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